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13. ABSTRACT (Maximum 200 Words) This DURIP grant made possible important technological advances in the AFOSR PRET Center on Homeostatic and Circadian Regulation of Wakefulness during Jet Lag and Sleep Deprivation: Effect of Wake-Promoting Countermeasures at the University of Pennsylvania improving the capability to investigate the neurobehavioral deficits associated with fatigue during performance. It provided the integrated systems for the ambulatory physiological measurement of sleep and sleepiness, as well as cardiovascular physiology in healthy individuals performing UAV maneuvers on Predatory systems during alert and fatigue conditions. This work is highly relevant to Air Force operations and DOD. In addition, DURIP funds allowed acquisition of the Neuroscan system for the acquisition of EEG during Neuroimaging. This will permit studies of the areas of brain activity relevant to understanding the effects of fatigue on performance. Thus the DURIP grant considerably streamlined and expanded the PRET Center's efforts to identify, evaluate and transition countermeasures to deficits associated with sleep deprivation and jet lag.					
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Effects of Sleep Loss and Jet-Lag in Operational Environments: Transitioning from Lab to Synthetic Task Environments Final Report

University of Pennsylvania

Principal Investigator: David F. Dinges, Ph.D.

**Summary Report:**

The equipment requested in the proposal was purchased and incorporated into the basic scientific research at the University of Pennsylvania site of the AFOSR PRET Center on Homeostatic and Circadian Regulation of Wakefulness during Jet Lag and Sleep Deprivation: Effect of Wake-Promoting Countermeasures. Our research is focused on bridging the critical and urgent gaps in knowledge to identify how fatigue affects performance measures that are operationally relevant to the Air Force and Department of Defense. The equipment purchased from this grant is being used to enhance current and pending AFOSR-funded research at the University of Pennsylvania and education on the effects of performance impairment when humans are exposed to jet lag and sleep deprivation, as well as wake-promoting countermeasures to prevent this impairment, by providing the first fully integrated system for physiological and neurobehavioral monitoring during synthetic task environment (STE) performance while subjects undergo sleep deprivation and/or circadian displacement.

The equipment purchased from the proposal is being used to assess the following specific aims:

- 1) Examine the physiological and neurobehavioral effects of sleep loss and/or circadian misalignment on Predator UAV synthetic task environment (STE) performance;
- 2) Assess the effects of countermeasures (e.g., naps, pharmacological interventions) on Predator UAV STE performance during sleep loss and/or circadian misalignment;
- 3) Examine the concordance of laboratory task performance (e.g., psychomotor vigilance, digit symbol substitution, mental arithmetic) with Predator UAV STE performance after sleep loss and circadian misalignment;
- 4) Investigate the magnitude of inter-individual differences in the effects of sleep loss and circadian misalignment on Predator UAV STE performance.

Synthetic Task Environments (STEs)

Synthetic task environments are designed to capture and measure fundamental elements of real-world tasks. They allow the experimenter to recreate abstract elements of work place tasks while maintaining a high degree of control over potential confounding variables. As such, they provide a compromise between laboratory and field approaches to research, enabling a degree of the face validity afforded by field studies while maintaining the experimental control of laboratory work. We selected the Predator UAV simulated task environment, which was developed by and for the Air Force and has direct relevance to Air Force operations, as the first we wish to implement. Dr. Kevin Gluck, Research Psychologist at the Air Force Research Laboratory and contributor to development of STE technology, is collaborating with us in several areas including, but

not limited to, training, experimental design, and interpretation of results from the Predator UAV.

Unmanned aerial vehicles (UAV) are becoming increasingly important in military operations. The Predator UAV was designed for use in surveillance and reconnaissance missions, capable of sending near real time information to ground control stations. The Predator UAV synthetic task environment was developed by the Warfighter Training Research Division of the Air Force Laboratory (AFRL/HEA), to be used as a research tool in government and academic environments. The Predator UAV STE consists of two adjacent display monitors, a keyboard and mouse. The virtual Predator is controlled using a joystick, throttle and rudder pedals. There are three tasks that can be performed: Basic Maneuvering, Landing and Reconnaissance.

The Predator UAV simulated task environment requires two dual-processor workstations (one for the subject and one for the operator) to run; one of these workstations must be equipped with two displays and various peripherals. The two workstations communicate via a network cable through a hub. In order to centralize software management and data harvesting, the STE system will be equipped with capability to communicate with a server (via the hub). In this fashion, a larger integrated system may also be set up for future STE efforts involving multiple subjects performing in the same synthetic task environment simultaneously.

For a fuller understanding of STE performance in the context of circadian rhythmicity and homeostatic sleep regulation, concurrent recordings of waking and sleep EEG and other polygraphic variables (e.g., EOG, EMG, respiration) are essential. In addition, assessment of cardiovascular parameters (heart rate, heart rate variability, spectral analysis of ECG) is important to understand STE performance in the context of the sympathetic and the parasympathetic nervous system. The balance of these systems is thought to mediate, at least in part, performance capability, and monitoring these systems is crucial for assessment of safety and efficacy of countermeasures (e.g., modafinil) to the effects of sleep loss and jet lag.

#### Rozzin Holter Monitors

We have integrated a Holter monitor for ECG recording (Rozzin Holter Monitor, Russ Biette and Associates, Glendale, NY) with the STE set-up, wired for temporal synchronization, to complement our ability to understand countermeasure effects during STE performance. The Holter monitor is a digital recorder and includes software for heart rate variability (HRV), spectral and statistical analysis. The system is capable of collecting 48 continuous hours of ECG data, and automated analysis and reporting.

#### Mallinckrodt "Suzanne" Polysomnographic Recording Systems

The proposed integrated equipment set-up will provide us with a unique capability to assess the potential of polygraphy-based predictors of sleepiness during simulated real-world performance. The polysomnographic recorder (Suzanne<sup>TM</sup>, Tyco Healthcare, Ottawa, Ontario), is being used as an attended system, for on-line data processing and time-locked integration with the STE. These systems provide on-line,

real-time and stop-action (manual search) evaluation of EEG, EOG, and ECG signals relative to integrated high-resolution video of the performer. Such information permits us to analyze second-to-second changes in behavior (e.g., distractibility) relative to neurobiology and neurobehavioral performance. In addition, we have recently integrated one of our primary neurobehavioral assessment tools (Psychomotor Vigilance Task-PVT) with the Suzanne System, further allowing for simultaneous assessment of neurobehavioral functioning and brain activity (EEG). Further, the Suzanne System contains state-of-the-art power spectral analyses (FFT) software for signal processing of EEG, EOG, and ECG relative to neurobehavioral performance and behavior.

#### Compumedics Neuroscan system (SynAmps<sup>2</sup>)

In order to further understand the potential mechanisms and functional neurobiology involved in the neurobehavioral and physiological responses to sleep deprivation and circadian disruption it is imperative to be able to synchronously record brainwave activity (EEG) and brain imaging, via MRI. In order to achieve simultaneous recordings of EEG and MRI scans, specialized polysomnographic recording systems that are compatible with MRI scanning equipment are available. Our purchase of the Compumedics Neuroscan system (SynAmps<sup>2</sup>) will allow us to simultaneously record gross changes in brain activity via the EEG, and examine which brain areas are being activated, as assessed by MRI, while subjects are undergoing sleep deprivation studies, in conjunction with circadian disruption.

The SynAmps<sup>2</sup> headbox allows for recording from 70 channels, using a Quik-Cap<sup>TM</sup> electrode montage system for multiple electrodes. In addition there is the capability for multiple headboxes to be linked together for a higher density recording system. Inputs for high-level signals are also provided, allowing for the simultaneous recording of time series data of other measures with the EEG. Data from the headbox is digitized immediately and transferred to the computer (via high-speed USB-2), increasing data transmission quality and reducing data loss. The computer system uses a standard windows computer and USB 2.0 interface.

#### -80°C Freezer

This project involved acquisition and use of a -80°C freezer as part of AFOSR PRET Center research being conducted on human performance capability and hormone profiles in relation to 88-hr simulated SUSOPS, and the effects of sleep loss and jet in operational environments.

In conclusion, this DURIP equipment grant has substantially improved and refined our measurements of an increased range of human physiological and neurobehavioral variables in the context of sleep loss and jet lag - from recording to data management, reduction and analysis.

Publications

N. L. Rogers, G. Maislin, H. P. A. Van Dongen & D. F. Dinges.  
Neurobehavioral and physiological effects of modafinil during escalating sleep  
deprivation. Neuropsychopharmacology, submitted.

Major Purchases under this agreement

<u>Item</u>	<u>Quantity</u>
Predator UAV STE systems	5
Data server for Predator system	1
Suzanne Polysomnography System	7
Rozzin Holter Monitors	6
Compumedics Neuroscan	1
Scientific Apparatus -80 Freezer	1